Comparing the Effects of Different Types of Aquatic Walking on Endurance and Electrical Activities of Spine Extensor Muscles in Men with Nonspecific Chronic Back Pain

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Abstract

Background: Chronic back pain is one of the most challenging medical problems worldwide that results in disability, physical problems, and high costs for the family and society. Therefore, it can be very beneficial to find an appropriate treatment with minimum side-effects for this disease. The present study attempted to compare the effects of different water gait protocols on the endurance and electrical activity of spine extensor muscles in men with nonspecific chronic back pain. **Methods:** The study adopted an experimental design in which 30 men with non-specific chronic back pain were selected through convenience sampling and using simple randomization method assigned into three groups of forward walking, backward walking, and sideways walking. Walking exercises were performed for 8 weeks, three sessions per week for 30 min. Twenty-four hours before and 48 h after the intervention, the endurance of spine extensor muscles and electrical activities were measured using the Ito test and electromyography, respectively. Data were analyzed in SPSS 23 using paired sample *t*-test and analysis of variance**.** **Results:** The results showed that backward walking in water significantly increases endurance and electromyography activities of spine extensor muscles ($P < 0.05$), while forward and sideways walking had no significant effect on these variables ($P > 0.05$). The results obtained from Bonferroni post-hoc test showed a significant difference between the strength of trunk extensor muscles and EMG of spinal cord extensor muscles in forward and backward water gait groups ($P = 0.001, 0.006$). **Conclusions:** According to the findings of this study, it seems that walking backward can be an effective therapeutic method for patients with chronic back pain.

Keywords: *Back pain, endurance, electromyography, hydrotherapy*

Introduction

Low back pain (LBP) is one of the most common problems that affects many people worldwide. LBP is defined as low back muscular pain or tightness, which may be with or without leg pain (i.e., sciatica).[1] This pain extends from the L2 vertebra to the sacroiliac joints and impairs health.[2] The lifetime incidence of LBP has been reported between 60 and 80% and is considered to be of economic and health importance.[3] Studies showed that approximately 70–85% of people suffer from LBP during their life, and in more than 80% of them, the injury has happened again.[4]

Back pain is categorized into three subgroups, namely acute back pain, regional back pain, and chronic back pain. Patients with acute, regional, and chronic back pain experience less than 6 weeks, 6–12 weeks, and more than 12 weeks of pain, respectively.[5,6] Chronic LBP has been one of the most challenging medical problems in industrialized and developing countries, imposing high economic costs on society.[7] Studies have shown that this affliction appears for the first time during adolescence,[8] develops up to the age of 60 years, and then subsides.[9,10]

Those who continue doing activities without bed rest following the onset of LBP are more likely to develop abdominal and dorsal trunk muscle atrophy and spinal dysfunction. Abdominal and dorsal trunk muscle dysfunction may contribute to spinal instability. In case these muscles are weakened, the function of the spine may be impaired, causing the patient to experience unfavorable conditions in the back muscles and the structures associated with them.[11] Accordingly, the trunk muscle

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strength and endurance could significantly contribute to pain reduction, as well as stability and normal function of the spine, especially in the lumbar region.[12] Spinal muscle dysfunction and changes in their structure can lead to fatigue and LBP.[4] The dorsal and lumbar muscles play a critical role in controlling spine motion and stability.

Meanwhile, deep muscles, which are involved in controlling the spine in dynamic conditions, play a more vital role in controlling intervertebral movements.[13] The spine consists of active structures (muscles) and passive structures (bones, joints, and ligaments). Active structures mechanically stabilize the spinal cord segments and are recognized as the first essential contributor to stability and balance acquisition.[14]

In patients with chronic LBP, ultrasound[15] and electromyography (EMG)[16,17] are used to evaluate the activity and function of the lumbar. In electromyography, frequency spectrums are used to study muscle fatigue and show the severity of fatigue and the extent to which it has improved in different muscles.[18] In this process, EMG signals are collected using electrodes placed on the surface of the contracted muscle, the corresponding frequency spectrum is plotted, and the median frequency is obtained.[19,20]

No specific treatment has yet been introduced for spinal disorders and LBP. In the past, hyperthermia, as well as electrical and stretching techniques, were used as treatments. Today, however, lumbar muscle engaging exercises are recommended as an optimal treatment solutions.[21] These exercises can vary depending on the exercise time, frequency, and type. Knox *et al*. (2017) investigated the impact of an 8-week physical fitness training course on individuals with chronic LBP. Subjects included 24 individuals with chronic LBP, who were assigned to experimental (n = 12) and control (n = 12) groups. The experimental group attended three sessions of physical fitness training per week for 8 weeks. The exercises were focused on unilateral arm flexion, rectus abdominis muscle, abdominal oblique muscle, and erector spinae muscles. Surface EMG was used to evaluate the performance of the subjects, showing increased fitness in the abdominal oblique muscle.[22]

Hydrotherapy is recognized as an active treatment technique for LBP. This method has many benefits and can, thanks to the weight loss and water-induced pressure, help individuals perform some activities.[23] Water properties that contribute to increased resistance and reduction of one's weight and the pressure exerted on joints make it easier for individuals to learn and experience less harmful exercises.[24] This therapy is a combination of aquatic exercises and physiotherapy where aquatic exercises are built on to contribute to rehabilitation modalities.[25] This therapy can also improve physiological impairments associated with osteoarthritis such as muscle weakness, proprioception, balance, cardiovascular fitness, and the restricted range of joint motion.[26] By floating themselves in water, elderly people and patients with chronic pain can improve their musculoskeletal and cardiovascular function and reduce mental problems such as stress, anxiety, depression, and fatigue.[27] Waller *et al*. (2009) showed that water rehabilitation alleviates pain and enhances the performance of patients with LBP and consequently encourages them to adhere to this therapy.[28]

In general, it can be argued that compared to other LBP therapies, hydrotherapy has some advantages such as buoyancy, the tensile strength of water, gravity control, and reduction of forces exerted on the spine.[2] As Astin *et al*. (2002) have pointed out, the ability to control gravity in water makes water gait useful for patients with LBP.[29] Water gait increases the rate and depth of breathing and, consequently, contributes to oxygen intake. The hydrostatic pressure of water also contributes to oxygen intake in the respiratory muscles.[30] Water produces 5–45 times as much resistance as air does;[31] hence, the speed of walking in water is 25–60% slower than on land. The pressure exerted on the spine straightening muscles while walking in the water is as much as the maximum pressure that could be exerted on them on land, and this could help improve the strength and endurance of these muscles.[32] According to Barker *et al*., the weightlessness experienced in water makes swimming, lying on water surface in the supine position, and aquatic exercises the best treatments for chronic LBP. They also believe that this therapy could reduce fatigue in patients with chronic LBP.[33] Custa-Vargas *et al*. (2012) compared deep water walking to standard general exercise in the water on non-specific LBP patients versus general practice care alone on pain and disability, reporting a lesser severity of pain in patients who practiced deep water walking.[34] Pires *et al*. (2015) investigated the effect of a 6-week aquatic exercise program on pain severity and functional disability of 32 patients with chronic LBP, reporting significant improvement in pain severity and functional disability of patients.[35] Sedaghati *et al*. (2016) investigated the effect of hydrotherapy and extension-based and flexion-based exercises on trunk muscular strength and pain intensity in women with non-specific chronic LBP. In this study, 68 women (aged 21–27 years) with chronic LBP were randomly assigned to four groups, namely, selective hydrotherapy exercise group, McKenzie exercise group, Williams exercise group, and a control group. The strength of trunk flexor and extensor muscles, as well as pain intensity, was measured before and after 12 weeks of exercise. The results showed a significant difference between trunk flexor and extensor muscle strength in the training groups. Pain reduction was observed in both two groups.[36]

Backward and forward water gait can help strengthen the lumbar, pelvis, and abdominal muscles. It can contribute to chronic LBP treatments and, consequently, lead to improved self-confidence, reduced anxiety, enhanced physical strength, improved quality of life,[37] and improved flexibility of the spine.[38] Given that the EMG activity of the lower limb muscles is higher during backward walking, it can be argued that the energy consumption rate is higher when walking backward.[39] Thus, backward walking, as compared to forward walking, can be associated with benefits such as higher muscle activity. Moreover, oxygen intake, as well as the metabolic and cardiopulmonary response, is higher in backward than forward walking.[40]

A consideration of the physical properties of water, the lack of studies on the impact of hydrotherapy on chronic LBP, and the impact of water gait on the strength and electrical activity of spinal cord extensor muscles in patients with chronic LBP underlie the motive for doing this study. In particular, the present study attempts to investigate the impact of forward, backward, and sideway water gait on the strength and EMG of spinal cord extensor muscles in men with non-specific chronic LBP.

Methods

Study design

The present study was a experimental study with a pretest–posttest design.

Patients and participants

Subjects comprised 30 male patients with chronic back pain (nonspecific chronic back pain at least in last 3 months) selected via convenience sampling method from among male patients with chronic back pain referring to Ghaem Hospital in Mashhad for the treatment of their LBP in 2018. They were allocated into three 10-member groups of walking forward, walking backward, walking sideways (left and right). Descriptive characteristics of the subjects are presented in Table 1. The inclusion criteria were having chronic low back pain for at least 3 months, and not having regular exercises in last 6 months.

The exclusion criteria were having pain during exercises, voluntary withdrawal from cooperation and lack of continuous attendance at training.

Intervention

Before the beginning of the training sessions, the subjects signed a written consent form to participate in the study. Subjects had back pain for more than 3 months, ranged in age from 30 to 50 years, and had no structural abnormalities. They performed water exercises in the shallow part of the pool for 8 weeks, three 30-min sessions per week. Exercise intensity was determined as per the intensity of the heart rate reserve, where the first eight sessions were performed with 50% intensity, the second eight sessions with 60% intensity, and the third eight sessions with 70% intensity (69) The heart rate reserve (HRR) is defined as the difference between the maximum heart rate and the resting heart rate (67).

Table 1: Mean±standard deviation of subjects' anthropometric characteristics

Factors Group	Age (years)	Height (cm)	Weight (kg)	*F*	*P*
Walking backward	39.6±5.4	179.8±6.1	76.1±9	0.77	0.471
Walking forward	40.7±6.5	177.8±4.9	77.4±7.5	1.66	0.209
Walking sideways	43.0±6.8	175.6±4.2	73.1±8	0.73	0.491

The evaluation of the EMG activity of the spine extensor muscles was performed using EMG on the spin erector muscles. The patient was seated comfortably in the sitting position on a chair adjustable to the length of the legs and trunk such that their thighs, knees, and right ankles were positioned at 90°. Moreover, to prevent extra movement, he was fixed to a chair with a belt on his thigh. Electrodes, which are a small needles, entered the muscle through the skin, so that the EMG activity of the muscle, picked up by the electrodes, was displayed on a monitor displaying the electrical activity as waves. The EMG measures the EMG activity of the muscle during rest, mild contraction, and severe contraction. After inserting the electrodes, the subject was asked to contract his muscle. A muscle that contracts more strongly indicates a higher number of activated muscle fibers and a greater potential for action.

The endurance of trunk spine extensor was assessed by the Ito test, which was conducted analogously to the original study by Ito *et al*. in 1996. The participants slept on their stomach at the examination table and a layer of foam 20 cm thick was placed under their bellies. Subjects were asked to bend their legs and contract their gluteal muscles to stabilize the pelvis, then raise their upper body for 15° above the horizon line by contracting the erector spine muscles. The duration of contraction in this position is calculated as the individual's score on the test.[41] The endurance and EMG activity of spinal extensor muscles were measured twice, in the pre-test (24 h before training) and post-test (48 h after the last training session).

Ethical statement

This research was approved by ethical committee of Isfahan University with the number of IR.UI.REC.1397.072.

Statistical analysis of data was performed in SPSS software version 23. Shapiro–Wilk test was used to determine the normality of the data distribution and the Levin test for the assumption of the equality of variances. ANOVA was used to determine between group differentiation of anthropometric characteristics. Paired *t*-test and repeated measures ANOVA were used for in-group comparisons, while Bonferroni post-hoc test was employed to compare between groups, after determining the normal distribution of the data and assuming equality of variances. The significance level was set at $P < 0.05$.

Results

Anthropometric characteristics of subjects are presented in Table 1. According to the significance level of one-way ANOVA test, there was no significant difference between the groups in any of the anthropometric characteristics ($P < 0.05$).

The findings obtained from inter-group comparisons with paired *t*-test as well as intra-group comparisons with ANOVA are presented in Table 2.

The results obtained from intra-group comparisons with paired *t*-test showed that the strength of trunk extensor muscles and the EMG of spine extensor muscles improved significantly in the posttest compared to the pretest phase in the walking backward group ($P = 0.001$ and $P = 0.016$, respectively), while in walking forward and walking sideways groups, the strength and EMG of spinal extensor muscles did not improve significantly ($P > 0.05$).

Inter-group comparisons with repeated measures ANOVA showed a significant difference in the strength of trunk extensor muscles (F = 10128/21, $P = 0.001$) and the EMG of spine extensor muscles (F = 499.18, $P = 0.001$) between the study groups.

The results obtained from Bonferroni post-hoc test for paired comparison of groups showed a significant difference between the strength of trunk extensor muscles in forward and backward water gait groups ($P = 0.001$). Nevertheless, no significant difference was observed in the muscle strength of forward and sideways water gait groups ($P > 0.05$).

The Bonferroni post-hoc test for comparison of EMG of spinal cord extensor muscles showed a significant difference between the backward and forward water gait groups ($P = 0.006$). Nevertheless, no significant difference was found between the EMG of spinal cord extensor muscles in backward and sideway water gait groups ($P > 0.05$) or the forward and sideways water gait groups ($P > 0.05$).

Discussion

In the present study, attempts were made to investigate the impact of different water gait scenarios on the strength and electrical activity of spinal cord extensor muscles in men with non-specific chronic LBP. Findings showed a significant difference between the strength of spinal extensor muscles in forward, backward, and sideways water gait groups. The results also showed that improvement in the strength of spinal extensor muscles in the backward water gait group was substantially more significant in the posttest than in the pretest. Comparison of posttest and pretest scores of extensor muscle strength in the forward and sideway water gait groups, however, showed no significant difference.

Subsequent findings showed that there was a significant difference between the EMG of spinal cord extensor muscles in the forward, backward, and sideways training groups. The results also showed that improvement in the EMG of spinal extensor muscles in the backward water gait group was considerably more significant in the posttest than the pretest. Comparison of posttest and pretest scores of EMG in the forward and sideways water gait groups, however, showed no significant difference between them.

The impact of kinesiotherapy on patients with LBP has been the subject of many studies. Shnayderman *et al*. (2012) compared walking and strength training in patients with LBP, finding that both exercises can improve the strength and endurance of trunk muscle as well as the performance of patients.[42] This finding is consistent with the findings of the present study. Sedaghati *et al*.[36] showed that there is a significant difference between trunk flexor and extensor strength in training groups. Similar to the current study, the subjects of their study comprised patients with chronic LBP who did hydrotherapy exercises as a training technique. Pereira *et al*. (2017) investigated the impact of Pilate's exercises (single leg stretching exercises and Chris-Cross exercises) on the EMG of trunk muscles in healthy subjects and patients suffering from chronic LBP. Subjects included 19 healthy individuals with the mean age of 28 years and 13 chronic LBP patients with the mean age of 30 years. The results showed that Chris-Cross exercises, compared to single-leg stretching, had the most significant impact on the stability of abdominal rectus and oblique muscles. Chris-Cross exercises also led to the activation of oblique muscles rather than multipolar and abdominal rectus muscle.[43] The findings of Shamsi *et al*.'s

Table 2: Results of paired *t*-test (inter-group comparison) and ANOVA (intra-group comparison) of variables in pretest and posttest

Variable	Group	Time point		Paired *t*-test		ANOVA test	
		Pre-test	Post-test	*t*	*P*	*F*	*P*
strength of trunk extensor muscles (second)	Walking backward	54.6±4.4	66.8±4.5	-5.50	0.001**	10128.21	0.001**
	Walking forward	53.4±3.4	54.3±4.1	-0.72	0.490		
	Walking sideways	56.2±3.2	57.3±3.7	-2.09	0.066		
EMG of spine extensor muscles (mv)	Walking backward	0.053±0.012	0.080±0.032	-2.97	0.016**	499.18	0.001**
	Walking forward	0.043±0.011	0.049±0.012	-1.15	0.279		
	Walking sideways	0.051±0.015	0.055±0.026	-0.36	0.728		

**P<0.05

study (2017) are also consistent with the findings of the present study. Shamsi *et al*. found that general backward stretching exercises can significantly contribute to spinal stability in patients with chronic LBP. In their study, they also used EMG to evaluate the status of the spine.[44]

Improvement of spinal muscle strength and electrical activity is of vital importance in patients with chronic LBP. It seems that water gait has effectively improved the strength and electrical activity of muscles and consequently improved LBP and the functional performance of the patient.[14]

Aquatic treatment programs mostly involve a reduction in weight-related forces. Patients who walk in water feel lighter and find it easier to move around. Thanks to buoyancy, they feel less pressure on their joints. Seemingly, the weight-loss sensation experienced in the water can eliminate or reduce muscle cramps and consequently improve muscle spasm. According to Baker, swimming, lying on the water surface in the supine position, and water gait are the best treatments for chronic LBP. These exercises actually reduce fatigue and lead to improved spine strength.[33] Buoyancy reduces the compressive forces exerted on the painful joints and muscles, allowing the muscles to move freely. Since water is a viscous liquid, strength exercises could be incorporated into the hydrotherapy programs of individuals with chronic LBP.[45] The viscosity of water creates a massage-like effect. In massage therapy, the pain fibers entering the central nervous system, which happen to be myelinated afferent fibers carrying the non-painful signals, can inhibit pain by affecting the communicating neurons.[46] Moreover, gravitational changes caused by water could, in practice, decline the pressure on the lumbar spine. Under the influence of resistance or viscous properties of water, as well as the water-induced hydrostatic pressure, the spinal and para-spinal muscles are strengthened and contribute to improvements in electrical activity and endurance of spine extensor muscles.[45]

Physical activity is also one of the mechanisms that could improve the endurance and electrical activity of spine muscles. By reducing cytokine production, physical activity can actually alleviate pain and improve physical performance.[47] The extensor muscles, which are inherently characterized by high fatigue thresholds and used to produce energy in the long term, could also contribute to endurance enhancement.[48] Thanks to these muscles, an individual might be able to maintain a stable posture for a long time. On the other hand, the ability to maintain the extension posture for a long time can be attributed to the high strength of the gluteal and hamstring muscles after exercise, because the lumbar spine is robustly linked to the large gluteal muscles and biceps femoris muscles through the thoracic myofascial and the sacrotuberous ligament.[49] Thus, these muscles are involved in energy generation and can help individuals maintain this posture. According to the literature, post-exercise muscle exhaustion leads to changes in neuromuscular activity patterns of the extensor, hip, and spine muscles. This is followed by an increase in the synergistic extensor muscle activity, which helps one maintain trunk extension posture for a longer period of time. Therefore, increased endurance and EMG of the spinal muscles can help one maintain the trunk extension posture.[50]

Mahjour *et al*. (2016) reported improvements in lumbar extensor muscle strength in patients with non-specific chronic LBP after 6 weeks of aquatic training. The similarity of findings (enhanced muscle strength) can be attributed to the number of training sessions and gender of the subjects.[51] Studies with consistent findings include that of Kim *et al*. (2010). In their research, they performed a comparative study of backward water gait, aquatic resistance exercises, and lumbar extension strength in male patients (mean age of 30) with intervertebral disc herniation or history of surgery. The subjects participated in a 6-week training course. Those in the aquatic training and resistance training group experienced enhancements in lumbar muscle strength that led to improvements in their overall performance. This finding is, to a degree, consistent with the findings of the present study. Increased lumbar muscle endurance and strength could also be attributed to the marked decline in gravitational force in water that could significantly decrease the pressure exerted on the lumbar spine. Moreover, thanks to the viscous property of water and the hydrostatic pressure it exerts, the muscles around the lumbar spine that are also known as para-spinal muscles gain more strength and consequently contribute to elimination or pain-inducing factors.[52]

Hessani Haghighi *et al*. (2016) investigated the effect of aquatic kinesiotherapy on the electrical activity of quadriceps femoris muscles and pain intensity in women with knee osteoarthritis. In this study, 30 elderly women were randomly assigned to experimental and control groups. The experimental group attended 20 aquatic kinesiotherapy sessions (5 sessions per week). Their findings showed that aquatic kinesiotherapy significantly increased the mean electrical activity of quadriceps femoris muscles.[53] This finding, however, was inconsistent with the findings of the present study. This inconsistency could be attributed to the aquatic training protocol, pain site, sex of subjects, and the duration of the aquatic training protocol.

In the present study, backward water gait, as compared to forward and sideways water gait, turned out to be one of the most effective ways to increase spine endurance and EMG. Studies have shown that backward water gait is an effective exercise that could positively affect an athlete's body and contribute to the rehabilitation of patients.[54] These exercises could also have beneficial effects on individuals with lower extremity injuries and increase their heartbeat and oxygen consumption rate.[55] Masumoto *et al*. (2007)

reported that backward water gait, as compared to forward water gait, could lead to more significant improvements in the strength and endurance of lumbar spine muscles and contribute to their activation.[56] Cole *et al*. (1996) found that backward water gait can lead to isometric contraction of the para-spinal muscles and consequently prolong muscle activity.[57] Masamuta *et al*. (2005) used the EMG to compare the impact of backward water gait and backward land gait on muscle activity and found that the electrical activity of all muscles, except for para-spinal muscles, declines during backward water gait. They showed that walking backwards in the water causes the most activation in the para-spinal muscles.[58]

Backward walking can be used for all age groups and individuals who need lower extremity rehabilitation so that they can change the pattern of activity in lower extremity muscles. The pattern of contraction of lower limb muscles in backward walking is opposite to that in forward walking.[59] Strengthening the lower extremity muscles via backward walking training can bring the power of counterpart muscles to a normal level and consequently improve muscle function and coordination in normal walking.[24] This mechanism of action also holds true for backward water gait.

In the elderly, the muscle fiber size, the number of type II fibers, the sensitivity of the central nervous system to exercise, the number of motor units, and motor unit activation potentials significantly decline as the individual grows older.[60] Along with aging, the number of type 2 fibers decreases and the time needed to bring about changes in the muscle structure increases. Increased training time in the elderly could, however, lead to changes in the electrical activity of muscles.[61]

Generally, trunk muscles' strength and endurance are weak in chronic LBP patients. Pain prevents these patients from performing rigorous activities and sometimes restricts their movements. Thus, the inadequate use of muscles could lead to atrophy and decreased muscles' flexibility and strength.[62] Atrophy and thinning of trunk muscles in patients with LBP can be among the reasons for lower muscle endurance in these patients. These individuals are also characterized by lower EMG in the thigh and lumbar muscles.[63] Effective hydrotherapy training can increase the tolerance of flexor muscles during the process of trunk stabilization and significantly improve pain and physical dysfunction by enhancing the trunk muscles' fatigue threshold.[64] Since this study found that increasing spine muscle endurance and electrical activity can significantly contribute to pain relief in patients with chronic LBP, the role of these factors cannot be easily ignored. Moreover, aquatic exercises in general, and backward walking in particular, are recommended as the best treatments that could be taken into account to improve rehabilitation in patients with chronic LBP.

The downside of the exercises we have suggested is that they are not applicable everywhere, and the type and dose of drugs that patients have been used, did not control by researchers. We suggest that aquatic exercises, specially backward walking, can improve the condition of individual with chronic low back pain.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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